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A New Species of *Leptolalax* (Amphibia, Anura, Megophryidae) from Peninsular Malaysia

Masafumi Matsui[1]*, Daicus M. Belabut[2,4], Norhayati Ahmad[3,4] and Hoi-Sen Yong[2]

[1]*Graduate School of Human and Environmental Studies, Kyoto University, Sakyo-ku, Kyoto 606-8501, Japan*
[2]*Institute of Biological Sciences, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia*
[3]*Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia*
[4]*Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia*

A new megophryid species, *Leptolalax kecil*, is described from the Cameron Highlands of Peninsular Malaysia on the basis of acoustic and morphological characteristics. It has an advertisement call dissimilar to that of other, congeneric species, and is the smallest of the known *Leptolalax*. It is similar to *L. pluvialis* from Vietnam in small body size, but differs from it in ventral color, and in the size and color of the pectoral gland. The distributional pattern of the new species is discussed.

Key words: Acoustics, *Leptolalax*, new species, Southeast Asia, taxonomy, zoogeography

INTRODUCTION

The megophryid genus *Leptolalax* Dubois, 1980 occurs from southern China and Myanmar through Thailand and Vietnam to Peninsular Malaysia (Malaya) and Borneo (Frost, 2008) and is composed of medium- to small-sized, forest-floor dwellers (Inger and Stuebing, 1997). Currently 22 species (including a dubious species, *L. lateralis* [Anderson, 1871]) are recognized (Frost, 2008), and 17 of these have been described within the last three decades (Dubois, 1983, 1987; Fei et al., 1991; Fei and Ye, 1992; Malkmus, 1992; Matsui, 1997, 2006; Inger et al., 1997, 1999; Lathrop et al., 1998; Ohler et al., 2000; Grismer et al., 2004). This is chiefly because many of the members of this genus are morphologically very similar and are thus difficult to identify. Some of those recently described taxa have been established on the basis of the acoustic characteristics of their calls, analyses of which have enabled the detecton of some cryptic members of this genus (Malkmus and Riede, 1993; Matsui, 1997, 2006).

Three species of *Leptolalax* have been recorded from Peninsular Malaysia: *L. gracilis* (Günther, 1872), *L. heteropus* (Boulenger, 1900), and *L. pelodytoides* (Boulenger, 1893) (Berry, 1975). In addition, *L. kajangensis* Grismer, Grismer, and Youmans, 2004 has been found from the adjacent island of Tioman (Grismer et al., 2004). However, records of *L. gracilis* from Peninsular Malaysia (Berry, 1975; Grandison, 1972) are doubtful (Matsui, 2006), and records of *L. pelodytoides* are also dubious because this species occurs in the more northern part of the continent (Matsui, 2006). During our field survey in Peninsular Malaysia, we collected four specimens of a small *Leptolalax* that is morphologically completely different from all four congeners recorded from this region, and that also emits unique calls distinctly different from those of all previously reported *Leptolalax* species. In this paper, we describe this taxon as new to science.

MATERIALS AND METHODS

We searched for frogs at night in the headwaters of a small stream along Trail 11 on the eastern slope of Gunong (Mt.) Jasar (1460–1600 m a.s.l.) in the suburbs of Tanah Rata town, Cameron Highlands. Recordings of calls were made in the field and indoors by using a cassette tape recorder (Sony TC-D5) with an external microphone (Sony ECM-23) and a digital recorder (Zoom H2). Temperature measurements were made with a quick-recording thermistor thermometer (Takara A 600) at the time of recording. The recorded calls were analyzed with the computer programs SoundEdit Vers. 2 or SoundEdit Pro (MacroMind-Paracomp) on a Macintosh computer, as described elsewhere (Matsui, 1997).

Specimens, with tissues taken for subsequent biochemical analysis, were fixed in 10% formalin and preserved in 70% ethanol, and stored at the Graduate School of Human and Environmental Studies, Kyoto University (KUHE) and Herpetological Collection in Universiti Kebangsaan Malaysia (UKMHC). Eighteen body measurements were taken mainly following the definitions by Matsui (1984, 1997): 1) snout-vent length (SVL); 2) head length (HL); 3) snout length (SL); 4) eye length (EL, including eyelid); 5) tympanum-eye length (T-EL); 6) tympanum diameter (TD); 7) head width (HW); 8) internarial distance (IND); 9) interorbital distance (IOD);

* Corresponding author. Phone: +81-75-753-6846;
Fax : +81-75-753-6846;
E-mail: fumi@zoo.zool.kyoto-u.ac.jp
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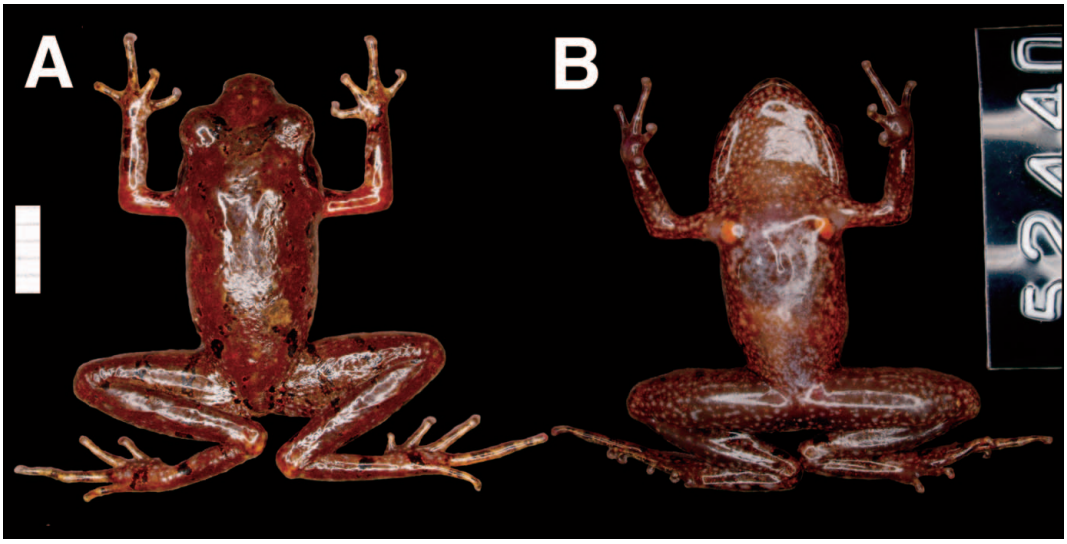

Fig. 1. **(A)** Dorsal and **(B)** ventral views of the male holotype of *Leptolalax kecil* (KUHE 52440). Scale bar, 5 mm.

10) upper eyelid width (UEW); 11) lower arm length (LAL); 12) inner palmar tubercle length (IPTL); 13) tibia length (TL); 14) foot length (FL); 15) hindlimb length (HLL); 16) inner metatarsal tubercle length (IMTL); 17) distance between anterior corners of eyes (ACED); and 18) distance between posterior corners of eyes (PCED). All measurements were made to the nearest 0.1 mm with dial calipers under a binocular dissecting microscope. For description of toe-webbing states, the system proposed by Savage (1975) was followed. For comparisons, we examined specimens of *Leptolalax* stored at museums. as described elsewhere (Matsui, 2006).

SYSTEMATICS

Leptolalax kecil sp. nov.
(Fig. 1)

Diagnosis

A small-sized toad of the genus *Leptolalax*, male 19.3–20.5 mm SVL (n=3), female 25.0 mm SVL (n=1); tibio-otarsal articulation reaching or even extending beyond snout tip in males; similar to *L. pluvialis* in small body size but differing in lacking a gland above axilla and dark botches on abdomen, and in having a larger pectoral gland. The new species has an advertisement call which is distinctly different from the calls of all congeners so far described.

Fig. 2. Ventral view of the foot of the holotype of *Leptolalax kecil*. Scale bar, 5 mm.

Etymology

The specific name *kecil* is Malay, denoting small.

Holotype

KUHE 52440, an adult male from Trail 11, Tanah Rata, Cameron Highlands, State of Pahang, Malaysia (4°28'40"N, 101°21'57"E, 1522 m a.s.l.), collected on 10 August 2008 by Masafumi Matsui and Daicus Belabut.

Paratypes

KUHE 52439 (adult female), KUHE 52441(adult male), and UKMHC 00505 (adult male); same data as for holotype.

Description of holotype (measurements in mm)

SVL 19.8; habitus moderately stocky; head longer (8.0) than broad (7.2); snout rounded, truncate in profile, projecting slightly beyond lower jaw; eye large, diameter (3.2) equal to snout length (3.2); canthus distinct, straight; lore slightly oblique, slightly concave; nostril lateral, below canthus, distinctly closer to tip of snout than to eye; internarial distance (2.6) slightly wider than interorbital distance (2.5), latter slightly wider than upper eyelid (2.4); pineal spot absent; tympanum distinct, diameter (1.4) less than half that of eye, and separated from eye by one-third of tympanic diameter (0.5); vomerine teeth absent; tongue notched, without papillae; a median, subgular vocal sac in the mid-ventral line; vocal openings posterior to rictus, close to eustachian tube openings.

Forelimb slender; fingers slender, unwebbed, first and fourth fingers subequal and longer than second; tips slightly swollen; inner palmar tubercle very large (1.2), not extending onto first metacarpal; smaller outer palmar tubercle; sub-

articular tubercles indistinct, replaced by long, low callous tissue; nuptial pads absent.

Hindlimb long (35.2); tibia long (11.0), heels overlapping when limbs are held at right angles to body; tibiotarsal articulation of adpressed limb reaching tip of snout; foot much shorter (9.7) than tibia; third toe longer than fifth; toe tips similar to those of fingers; webbing poorly developed, confined to bases of toes (Fig. 2), formula: I $1^{4}/_{5}$–2+ II 2–3+ III 3–4+ IV 4+–3 V; toes with lateral fringes; subarticular tubercles obscure, but elongate, replaced by large keratinous dermal ridges, a relatively short one on each of second and fifth toes, longer one on third toe, ridge covering entire underside of fourth toe except distal portion; inner metatarsal tubercle distinct, length (1.1) more than half of first toe length (1.7); no outer metatarsal tubercle.

Skin scattered with small tubercles above, including top of snout and head; a conspicuous, supratympanic ridge from eye to axilla; lateral sides scattered with larger tubercles; chest and abdomen smooth; very large (1.6), round pectoral gland and smaller round femoral gland; no supra-axillary gland or ventrolateral glandular ridges; skin of gular region not modified.

Color

In life, light brown dorsally on head and body, scattered with dark spots, including dark, reverse-triangle interorbital and triangle sacral spots, and an intervening large W-shaped spot; tympanum mostly masked with black; black band below canthus; lips barred with black; sides with several large, dark spots; groin with dark spot not extending onto thigh; arms marked laterally with black crossbars; elbow and upper arm without bar dorsally; thigh marked dorsally with black crossbars; sides of tibia with black bars, not continuous as bars across dorsal surface; posterior side of thigh with dark markings; an elongated white oval spot on the rear surface of thigh at distal one-third; chest and throat dusky, finely dotted with light brown; abdomen dusted with brown; ventral surfaces of legs dusky, finely dotted with light brown; pectoral gland dark orange; iris dark red in both halves.

In preservative, the aspects of the color pattern remain, but intensity of the color has been dulled and pectoral gland has faded to yellowish white.

Eggs

The single female had eggs in oviducts. The diameter of four ova ranged from 1.89–2.00 (mean±2SE=1.96±0.03) mm. Both the animal and vegetal poles were uniformly cream in color.

Call characteristics

Calls recorded in the field at a ground temperature of 18.5°C consisted of notes each emitted at an interval of ca. 6.3 s. Each note was composed of four pulse groups and lasted for 120–130 ms. Each of the first and second pulse groups consisted of one pulse, and each of the third and fourth groups of two pulses. The pulse-group gap was 40 ms. Frequency bands spread over the 2400–3800 hz range, and the dominant was 3200 hz. Harmonics were not evident, and frequency modulation and intensity modulation were very weak. Calls recorded at room temperature of 21.4°C

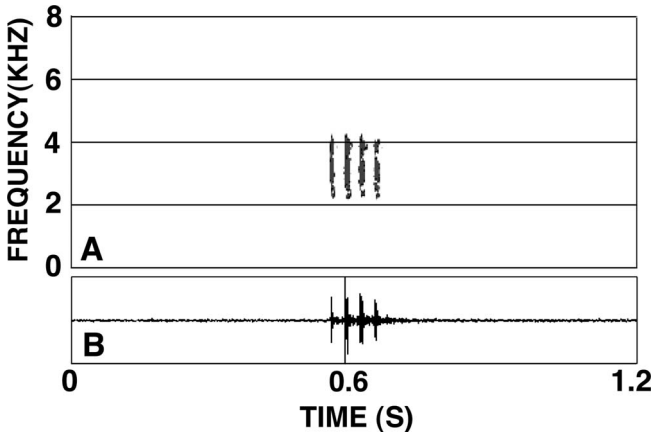

Fig. 3. Sonagram of an advertisement call of *Leptolalax kucil*.

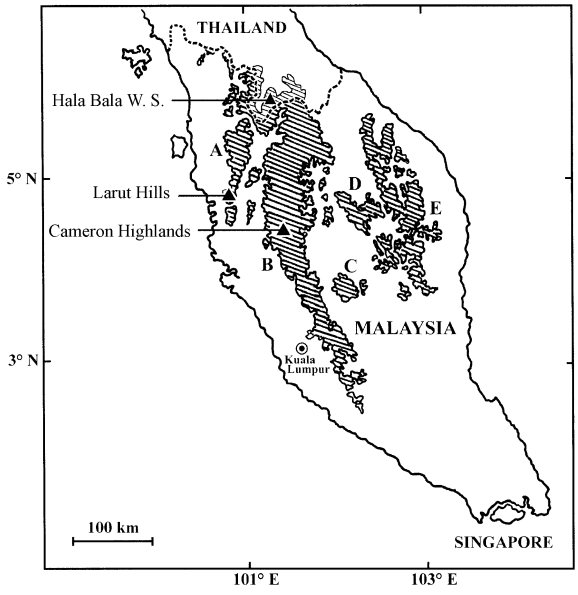

Fig. 4. Schematic map of the Malay Peninsula, illustrating the five mountain ranges (from west to east: A, Banjaran Bintang; B, Banjaran Titiwangsa; C, Banjaran Benom; D, Banjaran Gunong Tahan; E, Banjaran Timur) and the type localities of *Leptolalax kecil* (Cameron Highlands), *L. heteropus* (Larut Hills), and *L. solus* (Hala Bala Wildlife Sanctuary, Yala Province, South Thailand). Hatching indicates areas 300 m a.s.l. and above in elevation. Adopted from Leong and Lim (2003).

(Fig. 3) were similar to those recorded in the field, but the length of notes (110 ms) and pulse-group gap (30 ms) were shorter, and only a single pulse was present in the fourth pulse group.

Variation

The two male paratypes were morphologically similar to the holotype, but with eye diameter slightly smaller than snout length and interorbital distance slightly narrower than or equal to upper eyelid width, unlike the holotype.

The single female specimen (SVL=25.0 mm) was larger than the three males (19.3–20.5 mm, mean=19.9 mm). The small sample size limited statistical comparisons, but some

Table 1. Measurements of 16 characters in species of *Leptolalax* from the Malay Peninsula. SVL (mean±1SD, in millimeters), and the medians of ratios (R) of other characters to SVL, are followed by ranges in parentheses. See text for character abbreviations.

Species	Locality	Sex/N	SVL	RHL	RHW	RIND	RIOD	RUEW
L. kecil	Cameron	3M	19.9±0.60	40.4	36.4	13.2	11.4	11.7
			(19.3–20.5)	(37.6–41.5)	(34.6–38.3)	(12.4–13.3)	(10.2–12.8)	(11.4–11.9)
		1F	25.0	38.4	35.6	11.6	11.6	10.8
L. solus	Hala Bala	1M	27.6	42.4	35.1	9.8	10.5	11.2
L. heteropus	Larut	8M	25.2±0.49	41.2	37.8	10.4	10.9	12.9
			(24.6–26.0)	(40.3–43,5)	(36.1–40.7)	(9.8–10.7)	(10.4–11.9)	(11.5–14.1)
Species	Locality	Sex/N	RSL	REL	RTD	RE–TL	RLAL	RIPTL
L. kecil	Cameron	3M	16.8	16.1	6.8	2.8	50.3	6.4
			(15.9–16.8)	(15.0–16.2)	(6.2–7.8)	(2.1–2.8)	(49.2–50.5)	(5.9–7.0)
		1F	16.8	13.7	6.6	2.6	51.2	5.8
L. solus	Hala Bala	1M	15.2	15.6	6.5	3.6	54.0	7.2
L. heteropus	Larut	8M	15.2	15.4	6.1	3.6	54.1	5.9
			(13.8–16.5)	(14.7–17.3)	(5.5–6.5)	(3.1–3.9)	(52.7–55.7)	(4.7–6.9)
Species	Locality	Sex/N	RTL	RFL	RHLL	RIMTL		
L. kecil	Cameron	3M	55.7	48.8	177.8	5.0		
			(55.6–57.6)	(47.2–49.0)	(173.1–180.5)	(4.7–5.4)		
	Cameron	1F	53.8	48.6	175.6	4.3		
L. solus	Hala Bala	1M	54.0	46.0	170.3	4.0		
L. heteropus	Larut	8M	51.1	43.8	161.8	4.1		
			(50.0–52.7)	(40.5–45.8)	(155.6–166.9)	(3.6–4.4)		

dimensions relative to SVL seem to be sexually dimorphic. Males had larger values relative to SVL than the female in internarial distance (12.4–13.3% vs. 11.6%), upper eyelid width (11.4–11.9% vs. 10.8%), eye length (15.0–16.2% vs. 13.7%), inner palmar tubercle length (5.9–7.0% vs. 5.8%), tibia length (55.6–57.6% vs. 53.8%), and inner metatarsal tubercle length (4.7–5.4% vs. 4.3%). In contrast, the female had a longer lower arm relative to SVL than the males (51.2% vs. 49.2–50.5%). Tibiotarsal articulation of adpressed hind limb exceeded tip of snout in one male, but the articulation reached nostril in the female paratype.

Comparisons

Leptolalax kecil differs from all its congeners in the small body size. Until now, *L. pluvialis* Ohler, Marquis, Swan, and Grosjean, 2000 from Vietnam had been reported as the smallest *Leptolalax*. Males of this species are 21.3–22.3 mm in SVL (Ohler et al., 2000) and have a gray venter with dark gray marbling and a gland above the axilla (Matsui's own observation of the type series). In contrast, *L. kecil* has a uniformly dark venter and lacks a supra-axillary gland.

Leptolalax kecil also markedly differs acoustically from all known members of *Leptolalax* for which calls have been reported [*L. arayai* Matsui, 1997; *L. dringi* Dubois, 1987; *L. fuliginosus* Matsui, 2006; *L. gracilis* (Günther, 1872); *L. hamidi* Matsui, 1997; *L. heteropus*; *L. melanoleucus* Matsui, 2006; *L. pelodytoides*; *L. pictus* Malkmus, 1992; *L. solus* Matsui, 2006] (Matsui, 1997, 2006; Malkmus et al., 2002). All these species emit long, successive notes, each of similar duration, although the first note is usually longer than succeeding ones in *L. heteropus* and *L. solus*. Also, the pulses are generally not very clear. By contrast, *L. kecil* emits only one short, clearly pulsed call at a time.

Range

Known only from the type locality at Tanah Rata on the Cameron Highlands, Pahang, in the middle part of Peninsular Malaysia.

Natural History

Males were calling at night on the ground among dead leaves and stones, on slopes 1–5 m from the headwaters of a small stream (width<2 m). They were never found on leaves or rocks, unlike congeneric species. Early August must be within the breeding season, as evidenced by the appearance of a female just before spawning. Associated species observed were *Limnonectes laticeps* (Boulenger, 1882), *Microhyla annectens* Boulenger, 1900, *Philautus vermiculatus* (Boulenger, 1900), and *P. petersi* (Boulenger, 1900).

DISCUSSION

Malkmus and Riede (1993), Matsui (1997, 2006), and Malkmus et al. (2002) described the calls of some *Leptolalax* species from Borneo, Peninsular Malaysia, and Thailand. According to these reports, all known Bornean members and most continental members emit long calls with a succession of similar, short notes with indistinct pulses. Matsui (1997) indicated that frequency properties usually differ more than temporal ones among the Bornean species. Three species from Thailand, *L. pelodytoides*, *L. fuliginosus*, and *L. melanoleucus*, also have long, successive calls with different dominant frequencies like the Bornean members. Chinese *L. oshanensis* (Liu, 1950) and *L. liui* Fei and Ye in Fei, Ye, and Huang (1991) also have successive calls (Matsui, 2006). Exceptionally, *L. heteropus* from Peninsular Malaysia emits short calls, each with several successive notes, and *L. solus* from southernmost Thailand also has similar calls, though the temporal pattern differs between this species and *L. heteropus*. Pulses in these species are usually not clear. *Leptolalax kecil* differs from all continental and Bornean members in having calls characterized by a single, well-pulsed, short trill. Although *L. kecil* has not yet been found sympatrically with any of these species, the completely different call characteristics will surely function as a strong premating isolating mechanism between them.

The Cameron Highlands, where *L. kecil* was found, belongs to the Banjaran (mountain range) Titiwangsa, the largest of the five mountain ranges in Peninsular Malaysia. This main mountain range spans a distance of almost 400 km from the Thailand-Malaysia border to the southern state of Negeri Sembilan (Leong and Lim, 2003). Herpetological surveys of the Cameron Highlands date back to the 1930s, but findings of new frog species have never been frequent (Smedley, 1931). The species found most recently is the ranid *Hylarana banjarana* (Leong and Lim, 2003), whose type locality is close to that of *L. kecil*, but this ranid occurs widely in the Banjaran Titiwangsa (Leong and Lim, 2003). Therefore, extensions of the actual range of *L. kecil* to other regions of the Banjaran Titiwangsa might be expected. However, the likelihood of this does not seem to be high,

because *L. kecil* is restricted in habitat to the upper reaches of small streams at higher elevation than that of *H. banjarana*. The range of *L. kecil* is probably not as wide as the ranges of its congeners, although further studies are badly needed to understand the pattern of distribution and to infer the evolutionary history of the genus *Leptolalax*. Indeed, it is obvious that the herpetofaunal diversity in this key mountain range of the Peninsula has not yet been fully realized and that additional field studies are needed. Because logging was undertaken near the type locality of the new species and land development for vegetable cultivation was encroaching on the nearby forest at the time of our survey, this region also requires immediate attention from the viewpoint of biodiversity conservation.

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